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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 378

RECENT DEVELOPMENTS IN THE CONSTRUCTION AND OPERATION OF ALL-METAL AIRPLANES

By C. Dornier

From "Berichte und Abhandlungen
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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 378.

RECENT DEVELOPMENTS IN THE CONSTRUCTION AND
OPERATION OF ALL-METAL AIRPLANES.*

By C. Dornier.

Four years have elapsed since I had the honor of delivering an address in this hall on the occasion of the tenth regular session of the W. G. L. (Wissenschaftliche Gesellschaft für Luftfahrt). At that time I had to restrict myself to giving you a short review of what we had accomplished in the construction of all-metal seaplanes during the period 1914-1921. I called your attention to the fact that the basic materials for all our airplanes were sheets of duralumin and of steel. They were made proof against buckling by giving them the proper shapes. Welding was avoided on principle. All highly stressed parts were made of steel, while duralumin was principally used for subordinate and shaping parts.

The fundamental principles then in force have been retained by us up to the present day. The tendency to use steel wherever possible is more pronounced today than ever before. New possibilities have been opened up by the rust-proof steels recently put on the market. Naturally there was everywhere an en-

* "Neuere Erfahrungen im Bau und Betrieb von Metallflugzeugen," a lecture delivered before the W. G. L. in September, 1925. From the Year Book of the W. G. L. for 1925, No. 13 of "Berichte und Abhandlungen der W. G. L.," May, 1926, a supplement to "Zeitschrift für Flugtechnik und Motorluftschiffahrt."

deavor to simplify and cheapen the construction, and many refinements of shape were sacrificed.

Systematic experiments were continued with all new steels and light alloys. Although a few of these (Aludur, Lautal and Aeron), in the course of time, got into the same class with duralumin as regards breaking strength, elongation and workability, our experiments have thus far demonstrated that duralumin of German, English or Italian origin has not yet been equaled for weather resistance. The latest results, however, admit the hope that the endeavors put forth by the firms in question will succeed before long in overtaking duralumin even in the matter of weather resistance.

Experiments on the effect of the atmosphere and of sea water on the building materials employed by us have been carried on for years in the North Sea with the aid of the Hamburg Naval Observatory. Parallel experiments are being made at the Pisa Naval Observatory in the Mediterranean Sea. Metal sheets, sections, assemblies and experimental floats are being exposed to the action of the elements.

Fig. 1 shows one of these experimental bodies. It was made of duralumin and aludur. Moreover, for the sake of testing the effect of refining the rivets, rows of rivets, both refined and not refined, were prepared. The reciprocal action between dural or aludur and steel was tested on several steel fittings attached to sheets of light metal by iron rivets.

The most important results were as follows: The aludur section on the bottom of the float was almost entirely eaten off, leaving only a few vestiges near the rivet heads. This section was secured with refined rivets, which were themselves preserved in very good condition, no harmful effect from the corroded aludur section being apparent. The dural section fastened to the bottom of the float with unrefined rivets could barely be saved, as all the rivets had been eaten off. Except for a slight film, the dural section was very well preserved, although the protecting coat of aluminum bronze had scaled off. One end wall was made of aludur. This was corroded so badly as to leave large holes in the sheet metal. The remaining portions broke off under the slightest finger pressure. Three tension tests of the remains gave a mean breaking strength of only 5 kg/mm^2 (7112 lb./sq.in.) without any elongation. The duralumin walls of the float were intact. A slight corrosion showed only on the corners where the protecting coat had scaled off. The heads of the unrefined dural rivets were all eaten off, while the refined rivets were all in perfect condition.

The steel strips had a thin layer of rust. No harmful effect was noticeable between the steel and light metal. This is only another confirmation of what we established more than ten years ago, that steel and duralumin can be used together without hesitation. It was also found that alloyed steel

withstands corrosion better than ordinary carbon steel. According to our observations, both kinds of steel are of equal value as regards their behavior toward duralumin. ◦

Fig. 2 shows a duralumin sheet covered with barnacles and small mussels. The removal of the deposits from a portion of the sheet showed that it was entirely intact.

Long use of the seaplanes always show that smooth dural sheets are scarcely attacked (unless there are flaws from rolling) and, with proper care, will last for years. The portions of the duralumin which have been heated several times for easier working are, however, rapidly corroded. For this reason we avoid, in the construction of seaplanes, all methods which require thermal treatment.

In summing up, we may say, as the result of over ten years' observations, that metal airplanes, if the walls are not too thin and only duralumin and steel are used, will, with proper care, remain in usable condition for many years, even under very unfavorable climatic conditions. The expression "proper care" should be underlined, as this is often lacking. Conscientious care is, however, indispensable, especially as there is yet no entirely satisfactory protecting paint.

The wing structure of the seaplanes made by us in recent years is, in general, the same as described in my last lecture on "Metal Seaplanes." We employ both the so-called "full-

supporting" construction method and the "combination method" in which the sheet-metal covering simply replaces the diagonal bracing and metal wings with fabric covering. Fig. 3 shows an example of the combination method, a half-opened wing of the type Do. B (Komet III).

In 1921, I stated that in 1917-18 we were the first to build an airplane having a wing of light metal with a smooth supporting outer covering. This was a cantilever single-seat pursuit biplane of the type Do. DI, as shown in Fig. 9. Since the wing with a supporting covering has recently assumed renewed importance in technical circles, I take the liberty of showing you in Fig. 4 a cross section of this first historical wing. Your special attention is called to the stiffening of the skin by means of the special shape shown in the photograph, which is now found in exactly the same form in nearly all the wings with a smooth supporting outer covering, whether built in Germany or elsewhere. Without this shape, as developed by us, it is impossible to apply the covering in a practical manner for supporting, since the riveted angles or ordinary U-sections are, in effect, much inferior to the U-flange shapes and add too much weight. I still hold the opinion I expressed in 1921 that the wing with a supporting outer covering is not the only solution. The study of the shapes of wings of large dimensions has strengthened my conviction that the use of the supporting

covering has its limits.

Moreover, the expression "full-supporting outer covering" may give a wrong impression regarding the utilization of the material. It is not possible, without an excessive use of stiffenings, combined with time-robbing and expensive riveting, to make the sheet-metal covering yield more than 60% of its available strength for supporting, as regards pressure stresses, which are of decisive importance.

Fig. 5 shows the approximate tension distribution in a piece of supporting covering with special stiffening sections. The supporting strength of the sheet metal decreases as the distance from the stiffening members increases. It is probably manifest, without further explanation that, if only angle or ordinary U-sections were riveted on, instead of the U-flange sections, the utilization of the material would be still poorer, since the effect of the angle sections cover a considerably narrower zone than the special Dornier sections.

A certain fallacy regarding the economy of the "full-supporting construction method" is based on the above-mentioned facts. It is also a fact that all sheet-metal wings with supporting outer coverings, whether made by us or others, are heavier than the wings made by the combination method or with fabric covering. This holds good especially for increasing wing dimensions, for which reason we have employed the full-

supporting construction method only for relatively small spans.

When it is desired to design a wing with a given safety factor and with the smallest possible weight, then the endeavor to so construct the static superstructure that there will be the smallest possible number of parts (but highly stressed) will doubtless yield the best results. It is much easier to apply a force of 20 t once, than one of 2 t ten times. The greater the stress, the greater the cross section must be. The greater the cross section, the greater the utilization of the material and the smaller the weight employed for the transmission of the force.

The time at my disposal is too short for me to dwell much longer on the structure of the wing. I cannot, however, refrain from discussing briefly one of the most important problems which here come under consideration, namely, the effect of the aspect ratio on the weight of the wing. There is still an astonishingly widespread ignorance of the essential factors for the attainment of favorable aspect ratios. People enthuse over the large values of c_d^3/c_w^2 which they can attain with a large aspect ratio, but overlook the static consequences of an extreme aspect ratio and probably also often forget to consider that the weight in the performance equation is likewise in the third power. It can be easily demonstrated that any increase in the aspect ratio λ above 1:6 is not accompanied

by any increase in the ceiling. According to our experience, the best aspect ratio for a monoplane lies below $\lambda = 1:6$. Dr. Vogt, now in Japan, tested, at my suggestion, the effect of the aspect ratio on the ceiling and published his results under the title "Das günstige Seitenverhältniss" in No. 8 of the "Zeitschrift für Flugtechnik und Motorluftschiffahrt" for 1925.

Entirely apart from aerodynamik considerations, there is a purely static requirement, which restricts the aspect ratio of cantilever wings, namely, the limitation of the deformation of the wing. Experience shows that the ratio s of the overhang to the height of the spar cannot exceed a certain figure without weakening the wing too much. For rectangular wings with an approximately uniform profile, we found that s should not exceed 17 for steel, nor 15 for duralumin. If these figures are exceeded, the flanges must be made disproportionately heavy, in order to hold the deformation within allowable limits.

We bring this aspect ratio s of the spar (as determined by the requirements of a reasonable weight and restricted deformation within certain limits) into relation with the aspect ratio $\phi = t/h$ of the wing section or profile (t = chord, h = maximum thickness of profile). If we also introduce the aspect ratio $\lambda = b/t$ of the wing (by letting λ represent b and t and disregarding the decrease in the overhang due to the cabane or other bracing near the root of the wing) we obtain $s = \phi\lambda/2$. We then have $\phi\lambda/2 = 17$ or less for steel and 15 or less for

duralumin. For various values of ϕ we thus obtain the maximum values of λ given in

Table I

ϕ		4	5	6	8	10
λ	Steel	8.5	6.8	5.7	4.3	3.4
	Dural	7.5	6.0	5.0	3.8	3.0

Since a profile with $\phi = 5$ must already be regarded as a very thick one and profile with $\phi = 8$ can hardly be used for swift airplanes, it is obvious that the limits of λ are very narrow for cantilever structures. Our conclusions regarding the value of ϕ have recently been confirmed by American experiments with models ("The Comparison of Well-Known and New Wing Sections Tested in the Variable-Density Wind Tunnel," by G. T. Wiggins, Langley Memorial Aeronautical Laboratory). Of course the ratios change immediately when the wings are braced, as is now generally done. Then the relations between ϕ and λ hold good for only the overhanging portion and it is possible to reach, with relatively thin profiles, a λ of 6 or more with statically reasonable ratios. The same also holds true for biplanes with struts and, to some degree, for a wing with a trapezoidal plan.

The occurrence of resonance phenomena has caused a series of accidents within the last few years. I will describe a case

of resonance which caused us much racking of the brain and which may be of general interest. The airplane Falke (Figs. 6-7), which was tried out in every way in Switzerland and in America, suffered an accident in an exhibition flight in Madrid in 1923, which took place as follows:

In full-speed horizontal flight with throttle wide-open, a fluttering was suddenly noticed, followed by the bending of a wing tip from about the beginning of the aileron. The pilot brought the airplane into gliding flight, but could not regain horizontal flight, so that the airplane was seriously damaged and the pilot suffered a broken arm. The pilot stated that he suddenly felt extremely violent vibrations, so that he feared the engine would tear itself loose from its fastenings. He did not notice the upward bending of the wing tip. An examination of the wing, which was badly damaged in landing, afforded no clue to the cause of the accident. The airplane had been built according to the working drawings for the earlier type. The safety factor, 11.5, met the requirements for pursuit airplanes of its class, as established by the "Direzione Superiore del Genio e delle Costruzioni Aeronautiche" in Rome. Although every one was convinced that the safety factor was high enough, it was decided to raise it to 12.5. After several trial flights with the strengthened wings, the same phenomena suddenly reappeared. This time the wing tip bent in a steep left curve. The pilot immediately shut off the gas and landed in a swampy field, with a

simple capsizing, but without much damage to the airplane. The pilot was not injured.

While in the first accident, every one was entirely ignorant of the cause, this time both the pilot and persons on the ground saw that the wing vibrations originated in the ailerons. But why did not these phenomena occur in America? This question brought the solution. The only difference between the American type and the new type was that the ailerons were covered with fabric in America, while in the new type they were all-metal. The weights of the two kinds of ailerons were as 1 : 2. After the all-metal ailerons were replaced by cloth-covered ones, there was no further trouble.

The sheet-metal fuselage first built by us in 1917, with a smooth supporting covering and simple bulkheads or transverse frames, is still built without change and has found numerous imitators both at home and abroad. Mr. Weyl, in last year's regular meeting (of the W. G. L.) at Bremen, showed how much protection such fuselages offer in forced landings.

I will give another example. It has to do with a very severe crash, as the result of a forced landing caused by insufficient radiator cooling, which would ordinarily have resulted disastrously. As shown in Fig. 8, both the cabin and the pilot's seat remained intact. No one was hurt.

I will now give you a brief review of the development of

our landing gears, with the aid of a few illustrations. Fig. 9 shows the landing gear of the pursuit airplane Do. D I, built in 1918. This airplane has already been referred to in connection with the wings. The shock absorbers and axle were normal, while the streamlined struts of the landing gear were rigidly attached to the sheet-metal fuselage. There were no brace-wires. The landing gear of the Falke type was first made in 1922 and has not been changed. The continuous axle is missing. The shock absorbers are located inside the fuselage. While the landing gear of the Do. D I type was relatively difficult to exchange, that of the Falke type can be exchanged with the greatest ease. Its resistance to the air (drag) is reduced to the minimum. This landing gear has operated successfully, even in decidedly hard landings.

Fig. 10 shows the landing gear of a commercial airplane of the Komet II type, which has served as the model for a series of foreign landing gears. The axle is located between two streamlined outriggers and damped by ordinary rubber shock absorbers. The low position of the center of gravity, in conjunction with the shape of the fuselage, makes capsizing impossible.

Fig. 11 shows the form of landing gear employed at the present time on a commercial airplane, built in Germany, of the type Do. B. (Komet III). This form is not so elegant as the preceding, but costs less and can be exchanged quicker. Fig. 12 shows the landing gear and fuselage of a small training airplane.

I will now give you a brief review of the airplanes produced by us during the last few years. The pursuit airplane Falke has already been mentioned. This type was first equipped with Hispano-Suiza engines of various origins. With a load of 300 kg (661.4 lb.) the speed with an Italian H.-S. engine was 252 km/h (156.6 mi./hr.), while with an American H.-S. engine and a load of 360 kg (793.7 lb.) a speed of 260 km/h (161.6 mi./hr.) has been reached. With a B.M.W. IVa engine, results have been recently obtained, which are quite remarkable, considering that the experiments were made with a 1923 cell. With a load of 310 kg (683 lb.), the airplane climbed from 0 to 5000 m (16400 ft.) in 14.5 minutes, according to the official announcement. The wing has a rectangular shape with an aspect ratio of only 1 : 5. It has now been put on the market as a pursuit seaplane. One of this type, the "Seefalke," is equipped with a B.M.W. IVa engine.

The type Do. B (Fig. 13), also called Komet, is well known to most of us, since it is used in German air traffic. It represents a further development of the Komet II type. It can now be equipped, in Germany, only with engines not exceeding 360 HP. For the lack of a suitable German engine, the English engine Rolls Royce Eagle IX is now used.

The type Do. C (Fig. 14), built abroad, is a so-called "three-purpose" airplane. Equipped with engines of 400-600 HP., it can be employed for long-distance reconnoitering, bomb-drop-

ping and the transportation of military loads (troops, wounded, etc.). The maximum load, including fuel, is 1500-2000 kg (3307-4409 lb.) according to the power of the engine. The bottom of the fuselage and landing gear are so constructed that bombs up to 1000 kg (2205 lb.) can be readily attached and released. The regular armament consists of two fixed and two coupled revolving machine guns.

The seaplane Do. D (Fig. 15), built abroad, is related to the Do. C and can be used for reconnoitering at sea and for dropping torpedoes. The shaping of the floats was no easy matter. Fig. 16 shows front and rear views. At a recent official contest of the Japanese Navy, this seaplane alone was able to meet the very severe requirements.

The type Do. E (Fig. 17), is a seaplane with two or three seats, which is equipped with engines of 360-500 HP. and can likewise not be built in Germany. The armament is the same as for the type Do. C.

Fig. 18 represents a further development of the commercial seaplane "Delphin" which I first discussed in 1921, the pilot's seat being lowered. This seaplane was recently equipped with the B.M.W. IV engine, for which the normal load is 800 kg (1764 lb.).

I now come to the "Wal" type, about which I shall have somewhat more to say, because this seaplane holds a series of world records and has become internationally renowned for its

superior seaworthiness. The "Wal" has been built since 1919 with only slight modifications. The first one was equipped with two Maybach engines. Subsequently the 300 HP. Hispano-Suiza, the 400 HP. Liberty and especially, the 360 HP. R.-R. Eagle IX were used. Recently it has also been equipped with the Napier Lion and the Bristol Jupiter engines. It is an especial advantage of this type that the whole power plant is arranged nearly symmetrical to the center of gravity, so that the latter is not shifted by the installation of heavier engines. Its safety factor with engines up to 300 HP. is 5 : 1. For engines of over 300 HP., the wings are given a safety factor of 6. The "Wal" is built abroad, both as a military and as a commercial seaplane. Fig. 19 shows it as a military seaplane.

Table II

Characteristics of the two-engine boat seaplane "Dornier-Wal" with two Rolls-Royce Eagle engines.

Span	22.5 m	73.82 ft.
Chord	4.3 "	14.11 "
Wing area	97.0 m ²	1044.10 sq.ft.
Length	17.25 m	56.59 ft.
Height	47.00 "	154.20 "
Aspect ratio	5.24	

Power plant with housing, oil cooler and water	1515 kg	3340.00 lb.
Wing with struts and ailerons	640 "	1410.96 "
Hull with stubs and fittings	1100 "	2425.08 "
Tail group and controls	175 "	385.81 "
Total	3430 "	7561.85 "

Normal load 2000 kg 4409 lb.

Maximum " 2800 " 6173 "

Attained " 3100 " 6834 "

Normal wing loading 56 kg/m² (11.47 lb./sq.ft.)

Maximum " " 64 " (13.11 ")

Normal load per HP. 7.5 kg/HP. (16.53 lb./HP.)

Maximum " " " 8.6 " (18.96 ")

Consumption of Fuel and Oil

With throttle wide open 171 kg/h (377 lb./hr.)

At cruising speed
(155 km=96.3 mi./hr.) 135 " (298 ")

Flight Performances

At normal load of 2000 kg(4409 lb.)	With 2-360 HP. R-R Eagle IX	With 2-420 HP. Lorraine- Dietrich	With 2-450 HP. Napier Lion
Speed	185 km (115 mi.)/h	193 km (120 mi.)/h	200 km (124 mi.)/h
Climb 0-1000 m	7 minutes	6 minutes	5 minutes
Climb 1000-2000 m	11 "	9 "	7 "
Ceiling	3700 m (12139 ft.)	3900 m (12795 ft.)	4500 m (14764 ft.)

World Records of the Wal with R-R Eagle Engines

February, 1925.- Twenty world records (including eighteen not yet authenticated by the F.A.I.). The following records were made with a useful load of 2000 kg (4409 lb.):

Altitude	102%	above	old	record;
Speed	56%	"	"	"
Distance	154%	"	"	"

Metacentric Altitudes

Length metacentrum	$M_1F = 25.85 \text{ m}$	(84.81 ft.)
Metacentric altitude	$M_1G = 24.42 \text{ "}$	(80.12 ")
Width metacentrum	$MF = 7.92 \text{ "}$	(25.98 ")
Metacentric altitude	$MG = 6.49 \text{ "}$	(21.29 ")

Static Moments of Stability

5°	inclination	=	2.10	mt
10°	"	=	3.60	"
15°	"	=	4.25	"

Fig. 20 shows a commercial Wal, the characteristics of which are given in Table II. It is worthy of especial note that the excellent climbing ability and speed of this seaplane are combined with an aspect ratio of 5.2 and a slender wing section $\phi = 13$. Note also the exceptionally high ratio of the maximum useful load to the dead load. For the seaplanes used on

the Amundsen polar expedition, it was nearly 100%. It is normally 65-75%, values which, so far as we know, have never been attained by multi-engine seaplanes having an equal safety factor.

The hull is exceptionally strong, notwithstanding its relatively small weight. The ones used by Captain Amundsen took off from snow and ice, heavily loaded and under very unfavorable conditions.

Mr. Amundsen will soon report on his expedition and I cannot anticipate him in publishing his experiences. I will, however, cite one instance, which demonstrates the strength of the hull. The seaplane No. 25 had to be brought out of the water on to a place prepared for taking off. It taxied on to the ice with its own power. The ice then broke under the weight of the seaplane. While the stubs still glided on the ice, the body of the hull acted as an ice-breaker and pushed its way through ice about four inches thick for several hundred yards before it came to ice strong enough to support it. The hull then raised itself out of the water and continued its way on the ice.

I had the privilege of viewing the seaplane in Norway after its return. In order to produce the deformations found on the lower portions of the side walls, there must have been in places an ice pressure of at least $30,000 \text{ kg/m}^2$ ($6144.5 \text{ lb./sq.ft.}$). Nevertheless the hull remained perfectly water-tight.

After the compromise (which the Wal, as well as every other aircraft, represents), the factors which yielded such favorable

results are, in my opinion, as follows:

1. Small wing loading with low landing speed and consequent small stresses and a short take-off, hence great seaworthiness and good climbing ability.

2. Large broad hull, resulting in small pressure per unit area of the bottom, small submergence, easy starting and plenty of room in the hull.

3. An aspect ratio of 1 : 5.2, signifying favorable weight relations and the possibility of employing a good wing profile suited for high speed, a small span and a high safety factor.

4. Tandem arrangement of the engines, the simplest and best for inspection. Fig. 21 shows the condensed power plant of the Wal with two R.-R. Eagle IX engines.

Fig. 22 shows the attaching of the wheels which can be accomplished by two men. It is only necessary to insert the axle in the hole in the stub and then secure the wheel with a pin, to prevent its coming off.

Most hangars outside of Germany are made too narrow, so that the Wal is often run on to a small special transporting truck which enables it to be hauled sidewise (Fig. 23).

A two-engine land airplane of the type Do. N is being built abroad, with the tandem arrangement of the engines above the wing, which is characteristic of the Wal. The dimensions of this airplane are larger than those of the Wal. The lower

limit of the engines is 500 HP. It has a new kind of landing gear. Unfortunately, I can give no further data concerning this airplane. I mention it only for the sake of completeness.

On the assumption that it is of general interest to have reliable data on the weight relations of metal airplanes, Fig. 24 gives the weights of the various airplane parts of eight Dornier airplanes in percentages of the dead load (structural weight) plotted against the dead load. The diagram compares airplanes with dead loads of 400-7000 kg (882-15432 lb.). The weight is divided into four groups: power plant, wing structure, fuselage and tail group. The diagram covers the most divergent types of land airplanes and seaplanes, military commercial and giant airplanes. The fuselage weight includes the weight of the landing gear and tail skid and of the stubs on boat seaplanes or "flying boats." The tail group comprises all the steering apparatus, including that in the pilot's cockpit, etc. On commercial airplanes the weight of the cabin fittings is omitted for the sake of fairer comparisons. In considering the curves, it should be remembered that they deal in part with airplanes of very different wing loadings and loads per horsepower.

All the weights were carefully determined both by accurate weighing of the separate parts and of the completed airplane. Only in the case of the Do. N, a few of the partial weights were determined from the drawings, because this type is not now

equipped with the B.M.W. VI, but with a more powerful foreign engine. These weights do not deviate, however, more than 3% from the reality.

The weight of the marine type R III No. 1431 was determined by the former Seaplane Experiment Squad (SVK). This type has long been obsolete and was included only to enable certain conclusions regarding the weight relations for a considerable increase in the dead load above what is now customary for metal airplanes. This type had, in addition to the boat, a fuselage located above the wing, an arrangement for the purpose of increasing the seaworthiness, but which naturally increased the weight also. Hence, in this case, the fuselage weight includes the weight of the boat, which explains the relatively large fuselage weight of this type. Our determinations for much greater dead loads show a normal fuselage weight of not more than 26-28% of the total weight, i.e., exactly the same as for airplanes of about 1500 kg (3307 lb.) dead load.

Time is lacking to go further into the subject of the values and relations included in Fig. 24. I intend to publish an article before long on the question of increasing the size of airplanes and will improve the occasion to discuss the effect of structural and aerodynamic measures on the weight of metal airplanes.

During recent years much has been said and written on the enlargement of airplanes. Many writers have drawn the conclu-

sion that there are practical limits to such enlargement and that it would be possible only by considerably increasing the wing loading. I cannot subscribe to this view. Of course the wing loading can be increased with increasing weight of the airplane (i.e., with increasing dimensions), but the increase in the wing loading is naturally limited by the necessary limitation of the landing speed, as likewise by the requirement of a short start. This is specially true of seaplanes. Seaworthiness and high landing speed can never be combined, since one excludes the other. A rational enlargement of airplanes is possible, however, without endangering the safety by too high a landing speed necessitated by excessive wing loading. Fig. 24 shows, for example, that the wing structure of the Wal type is no heavier proportionally with its 97 m^2 (1044 sq.ft.) wing area, than that of the Libelle type with 15.5 m^2 (166.8 sq.ft.) and the same safety factor.

The wing structure of the R III type (Navy No. 1431), with 226 m^2 (2432.6 sq.ft.) wing area is, with fourfold safety factor, in proportion, approximately equivalent to that of the small Libelle. It must be remembered that the R III type was produced in 1917-18 and that the static relations of the wing were rather unfavorable, due to the small height of the spars. It would now be easy to build a wing structure of like area and like weight with a safety factor of six. The power-plant weight of such an airplane would not change appreciably, if modern 400 HP. engines

were installed in place of the 245 HP. Maybach engines then used, since the 245 HP. Maybach engine of that time weighed 430 kg (948 lb.) without accessories, while a modern 400 HP. engine weighs only about 400 kg (822 lb.). It follows, therefore, that a modern airplane of about 7000 kg (15432 lb.) with 1600 HP. and 226 m² (2432.6 sq.ft.) wing area and a safety factor of six is possible. With a load of 4500 kg (9920.8 lb.), the load per horsepower would then be 7.2 kg (15.87 lb.). The wing loading would be 51 kg/m² (10.45 lb./sq.ft.), which would correspond to a landing speed of not over 75 km (46.6 mi.) per hour. Of course, the carrying capacity of such an airplane would be much greater than 4500 kg (9920.8 lb.) since, with a wing area of 226 m² (2432.6 sq.ft.) and a modern wing section, the wing loading can be raised above 60 kg/m² (12.29 lb./sq.ft.), without unduly increasing the landing speed.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.

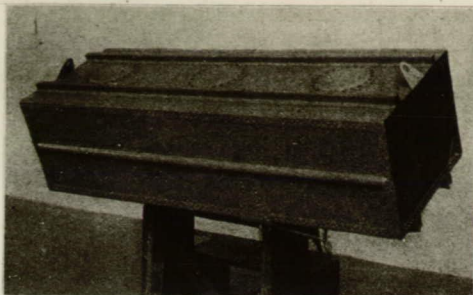


Fig.1 Experimental body for testing its resistivity to the weather.

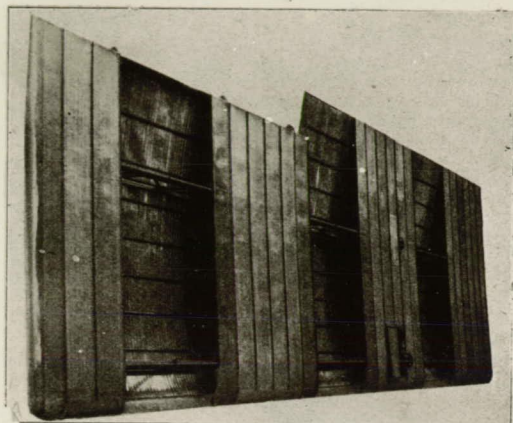


Fig.3 Half-opened wing of type Do.B.



Fig.3 Duralumin sheet covered with barnacles & mussels.

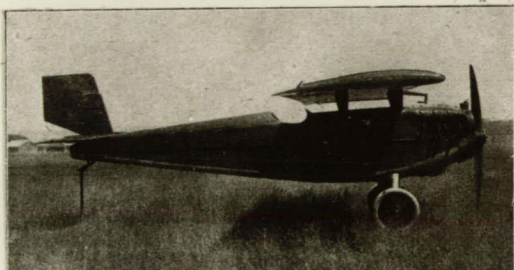


Fig.7 Pursuit plane Falke, 1922 type.

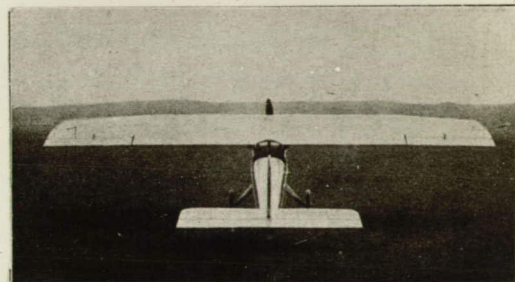


Fig.6 Pursuit plane Falke, 1922 type.

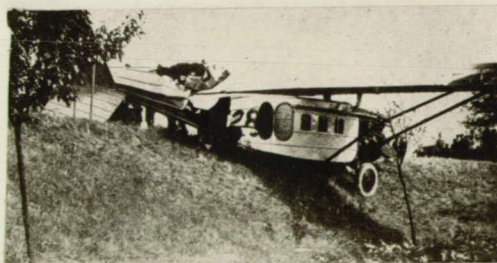


Fig.8 Behavior of metal fuselage in a heavy fall.



Fig.9 Landing gear of a 1918 all metal pursuit plane Do.DI.

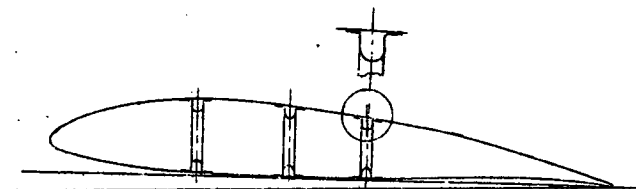


Fig.4 Section of first wing with smooth surface.

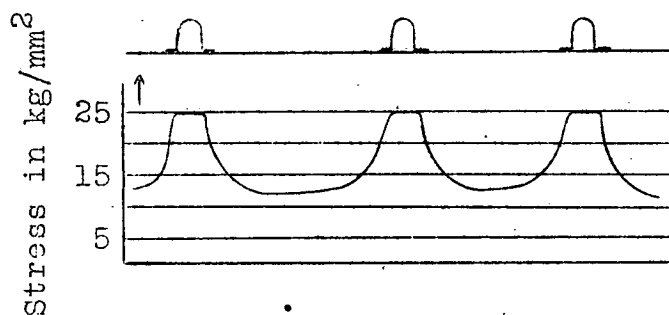


Fig.5 Stress distribution in a metal sheet used as a supporting covering.

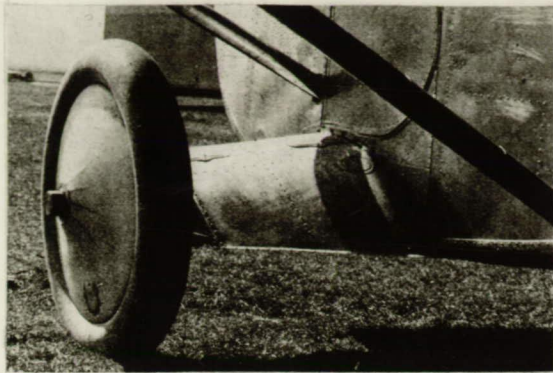


Fig.10 Landing gear of Komet II.



Fig.11 Landing gear of type Do.B (Komet III).



Fig.12 Training plane with Bristol Lucifer engine.



Fig.14 Airplane Do.C.

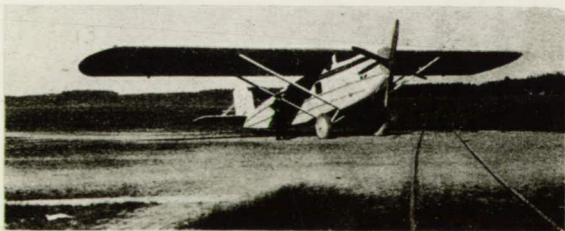


Fig.13 Commercial airplane Do.B.

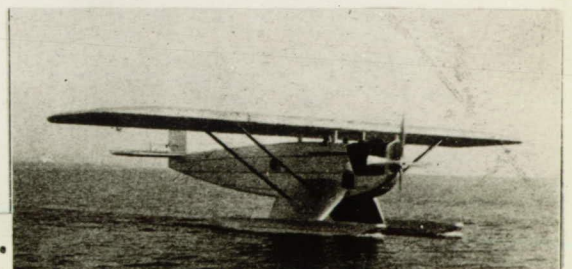


Fig.15 Torpedo pursuit plane Do.D.

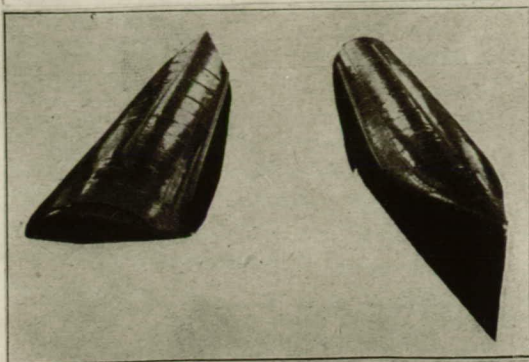


Fig.16 Front & rear views of floats of type used on Do.D.



Fig.17 Observation seaplane Do.E.

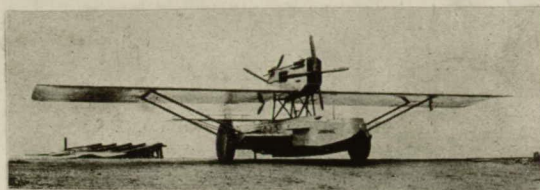


Fig.19 Boat seaplane "Wal", military type.



Fig.18 Boat seaplane "Delphin".



Fig.20 Boat seaplane "Wal" commercial type.



Fig.21 Power plant of "Wal".

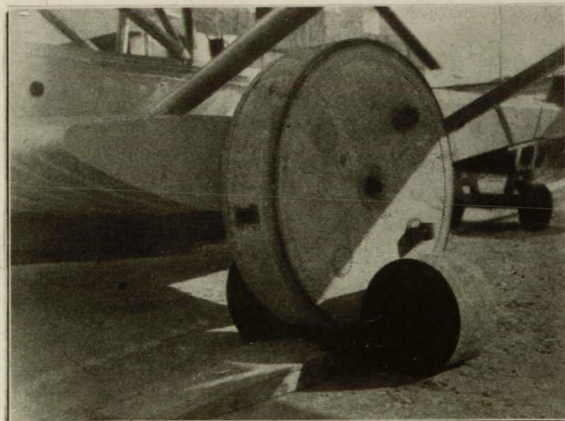
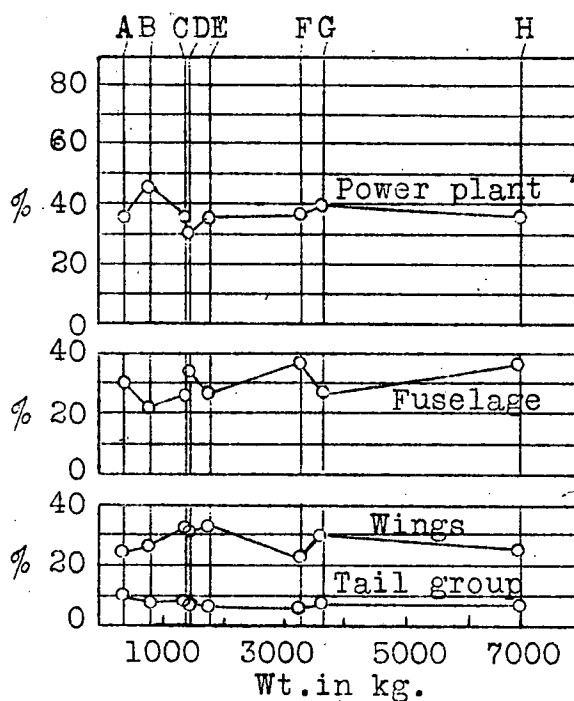


Fig.23 Rollers for moving the "Wal" sidewise.



Fig.22 Attaching the wheels.



A	Libelle	Siemens	80 HP.	Safety factor	n = 6
B	Falke	His.Suiza	300HP.	"	" n =12.5
C	Komet II	R.R.	260HP.	"	" n =5
D	Delphin	BMW IV	250HP.	"	" n =5
E	Do.C	R.R.	360HP.	"	" n =6
F	Wal 2	R.R.	720HP.	"	" n =6
G	Do.N 2	BMW VI	1000HP.	"	" n =6
H	R III	4 Maybach	980HP.	"	" n =4

Fig.24 Wts. of parts of 8 different Dornier airplanes of 400-7000 kg(882-15,432 lb.)dead load.